

## CLAIMS

What is claimed is:

1. An apparatus, comprising:  
a stage having a surface;  
a first blade coupled to the stage, the first blade extending perpendicular to the surface of the stage;  
a frame having a surface, the stage pivotally coupled to the frame;  
and  
a second blade coupled to the frame, the second blade extending perpendicular to the surface of the frame, the second blade being parallel with the first blade.
2. The apparatus of claim 1, wherein a gap having a distance is formed between the first blade and the second blade, and wherein the first blade is configured to move relative to the second blade along a range, the distance between the first blade and the second blade is maintained substantially constant throughout the range of motion.
3. The apparatus of claim 2, wherein the first blade is configured to move relative to the second blade along a range and wherein the first blade and second blades are maintained substantially parallel throughout the range of motion.

4. The apparatus of claim 1, wherein the first blade has a first length, the second blade has a second length, and wherein the first length is tapered.
5. The apparatus of claim 1, wherein the first blade has a height extending from the surface of the movable frame, a length extending from a first side to a second side, and wherein the first side has a first width and the second side has a second width different than the first width.
6. The apparatus of claim 3, wherein the first blade is configured to move relative to the second blade in the presence of a potential between the first and second blades.
7. The apparatus of claim 3, wherein the first blade has a length and wherein the range of motion of the first blade is determined by the length.
8. The apparatus of claim 1, wherein the stage is pivotally coupled to the frame with a flexure.
9. The apparatus of claim 8, wherein the flexure comprises a plurality of torsion beams.
10. The apparatus of claim 9, wherein the plurality of torsion beams are substantially parallel to one another.
11. The apparatus claim 9, wherein each of the plurality of torsion beams has a length and wherein the plurality of torsion beams are non-parallel along portion of the lengths.

12. An apparatus, comprising:  
a frame;  
a stage pivotally coupled to the frame;  
a first blade coupled to the stage; and  
a second blade coupled to the frame, the second blade configured to move relative to the first blade through a range of motion, the second blade remaining parallel with the first blade throughout the range of motion.
13. The apparatus of claim 12, wherein the first blade extends perpendicular to the stage and the second blade extends perpendicular to the frame.
14. The apparatus of claim 12, wherein a gap having a distance is formed between the first blade and the second blade, and wherein the distance between the first blade and the second blade is maintained constant throughout the range of motion.
15. The apparatus of claim 12, wherein the first blade has a tapered length.
16. The apparatus of claim 12, wherein the flexure comprises a plurality of torsion beams.
17. A method, comprising:  
forming a gap having a distance between a first blade and a second blade;

applying an electrostatic potential between the first blade and the second blade to generate a force to move the first blade relative to the second blade along a range of motion; and

maintaining the distance of the gap between the first and second blades through the range of motion.

18. The method of claim 17, further comprising adjusting the force along the range of motion.

19. The method of claim 18, wherein the adjustment of the force is maintained approximately linear along the range of motion.

20. The method of claim 17, wherein the first blade and second blade each have a surface area and wherein a portion of the surface areas overlap along the range of motion.

21. The method of claim 20, further comprising increasing the overlapping portion of the surface areas.

22. The method of claim 17, wherein the first blade is coupled to a stage, the stage pivotally coupled to a frame, and wherein applying the electrostatic potential generates a torque to rotate the stage.

23. An apparatus, comprising:  
a central stage;  
a movable frame disposed around the central stage; and  
a fixed frame disposed around the movable frame, the central stage coupled to the movable frame with a first flexure, the movable frame

coupled to the fixed frame with a second flexure, the first flexure comprising a first plurality of torsion beams, wherein the central stage and the movable frame are capable of decoupled motion.

24. The apparatus of claim 23, wherein the second flexure comprises a second plurality of torsion beams.

25. The apparatus of claim 24, wherein the central stage and the movable frame each have a surface and wherein the apparatus further comprises:

a first blade coupled to the central stage, the first blade extending perpendicular from the surface of the central stage; and

a second blade coupled to the movable frame, the second blade extending perpendicular from the surface of the movable frame, the second blade being parallel with the first blade.

26. The apparatus of claim 25, wherein a gap is formed between the first blade and the second blade, the gap having a distance.

27. The apparatus of claim 26, wherein the first blade is configured to move relative to the second blade along a range and wherein the distance between the first blade and the second blade is maintained substantially parallel throughout the range of motion.

28. The apparatus of claim 23, wherein the movable frame is pivotally coupled to the first plurality of torsion beams.

29. The apparatus of claim 28, wherein the fixed frame forms a cavity and wherein the first plurality of torsion beams suspends the movable frame in the cavity.

30. The apparatus of claim 23, wherein the movable frame comprises:  
a main body coupled to the second flexure;  
an end bar coupled to the first flexure; and  
a support member coupled between the main body and the end bar.

31. The apparatus of claim 30, wherein the support member is coupled to the main body at a non-perpendicular angle.

32. The apparatus of claim 13, wherein the first flexure comprises a pair of torsion beams.

33. The apparatus of claim 32, wherein each of the torsion beams has a length and wherein the torsion beams are parallel to each other along their lengths.

34. The apparatus claim 13, wherein the second flexure comprises a pair of torsion beams, each of the torsion beams having a length and wherein the torsion beams are non-parallel along a portion of their lengths.

35. An apparatus, comprising:

a central stage;

a movable frame disposed around the central stage;

a fixed frame disposed around the movable frame;

a first blade coupled to the central stage perpendicular to the surface of the central stage; and

a second blade coupled to the movable frame perpendicular to the surface of the movable frame, the second blade being parallel with the first blade.

36. The apparatus of claim 35, wherein a gap having a distance is formed between the first blade and the second blade, and wherein the first blade is configured to move relative to the second blade along a range, the distance between the first blade and the second blade is maintained substantially constant throughout the range of motion.

37. The apparatus of claim 35, wherein the first blade is configured to move relative to the second blade along a range and wherein the first blade and second blades are maintained substantially parallel throughout the range of motion.

38. The apparatus of claim 36, further comprising a mirror coupled to the central stage.

39. The apparatus of claim 35, wherein the central stage is coupled to the movable frame with a first flexure and the movable frame is coupled to the fixed frame with a second flexure, the second flexure orthogonal to the first flexure.

40. The apparatus of claim 39, wherein the first flexure comprises a pair of parallel torsion beams.

41. The apparatus of claim 39, wherein the second flexure comprises a pair of non-parallel torsion beams.

42. The apparatus of claim 39, wherein the movable frame comprises:  
a main body coupled to the second flexure;  
an end bar coupled to the first flexure; and  
a support member coupled between the main body and the end bar.

43. The apparatus of claim 42, wherein the support member is coupled to the main body at a non-perpendicular angle.

44. An apparatus, comprising:  
a stage having a surface;  
a first blade coupled to the stage, the first blade extending perpendicular to the surface of the stage;  
a frame having a surface, the stage pivotally coupled to the frame with a flexure having a plurality of torsion beams; and



a second blade coupled to the frame, the second blade extending perpendicular to the surface of the frame, the second blade being parallel with the first blade, wherein a gap having a distance is formed between the first and second blades, the distance maintained substantially uniform when an electrostatic potential is applied between the first and second blades.

45. An apparatus, comprising:

a plurality of actuators, each of the plurality of actuators comprising:

a central stage;

a movable frame disposed around the central stage;

a first blade coupled to the central stage perpendicular to the surface of the central stage; and

a second blade coupled to the movable frame perpendicular to the surface of the movable frame, the second blade being parallel with the first blade; and

a fixed frame disposed around the movable frame of the plurality of actuators.

46. The apparatus of claim 45, wherein the fixed frame comprises a plurality of isolation segments.

47. A method for fabricating a microelectromechanical apparatus comprising:

forming first trenches on a first side of a substrate;

forming a layer of dielectric material on the first side of the substrate and filling the first trenches with the dielectric material to provide electrical isolation;

patterning a masking layer on a second side of the substrate that is opposite to the first side of the substrate;

forming vias on the first side of the substrate;

metallizing the first side of the substrate;

forming second trenches on the first side of the substrate to define structures;

deeply etching the second side of the substrate to form blades;

etching to release the structures.

48. The method of claim 47, further comprising attaching a protective structure to the second side of the substrate prior to etching through the second trenches.

49. The method of claim 47, wherein the substrate comprises a silicon wafer.

50. The method of claim 47, further comprising attaching a protective lid to the first side of the substrate.

51. The method of claim 47, wherein the dielectric material is silicon dioxide.

52. The method of claim 47, further comprising depositing a second metal layer on the first side of the substrate after metallizing the first side of the substrate in order to form a reflective surface.

53. The method of claim 47, further comprising forming a passivation layer on the first side of the substrate after metallizing the first side of the substrate.

54. The method of claim 48, wherein the protective structure comprises a base wafer.

55. The method of claim 50, wherein the protective lid comprises glass.

56. A method for fabricating a microelectromechanical apparatus, comprising:

    patterning a masking layer on a second side of a substrate having a second side that is opposite to a first side of the substrate;

    deeply etching the second side of the substrate to form blades;

    attaching a protective structure to the second side of the substrate;

forming first trenches on the first side of the substrate;

forming a layer of dielectric material on the first side of the substrate and filling the first trenches with the dielectric material to provide electrical isolation;

forming vias on the first side of the substrate;

metallizing the first side of the substrate;

forming second trenches on the first side of the substrate to define structures;

etching to release the structures.

57. The method of claim 56, wherein the substrate comprises a silicon wafer.

58. The method of claim 56, further comprising attaching a protective lid to the first side of the substrate.

59. The method of claim 56, further comprising thinning the first side of the substrate prior to forming the first trenches.

60. The method of claim 56, wherein a side of the protective structure facing the second side of the substrate includes a recess.

61. The method of claim 56, wherein the dielectric material is silicon dioxide.

62. The method of claim 56, further comprising depositing a second metal layer on the first side of the substrate after metallizing the first side of the substrate in order to form a reflective surface.

63. The method of claim 56, further comprising forming a passivation layer on the first side of the substrate after metallizing the first side of the substrate.

64. The method of claim 56, wherein the protective structure comprises a base wafer, wherein attaching the protective structure to the second side of the substrate comprises fusion bonding the base wafer to the second side of the substrate.

65. The method of claim 56, wherein the protective lid comprises glass.

66. A method for fabricating a microelectromechanical apparatus comprising:

forming a layer of dielectric material on a first side of a silicon-on-insulator (SOI) substrate;

patterning a masking layer on a second side of the SOI substrate that is opposite to the first side of the SOI substrate;

forming vias on the first side of the SOI substrate that extend through a buried oxide layer of the SOI substrate;

metallizing the first side of the SOI substrate;

forming trenches on the first side of the SOI substrate to define structures;

forming a passivation layer on the first side of the substrate on metallization of the first side of the SOI substrate and on sidewalls of the vias and trenches of the first side of the SOI substrate;

deeply etching the second side of the SOI substrate to form blades that reside beneath the respective vias;

etching to release the structures.

67. The method of claim 66, further comprising attaching a protective structure to the second side of the SOI substrate prior to etching through the trenches.

68. The method of claim 66, wherein the SOI substrate comprises an SOI wafer.

69. The method of claim 66, further comprising attaching a protective lid to the first side of the SOI substrate.

70. The method of claim 66, wherein the dielectric material is silicon dioxide.

71. The method of claim 66, further comprising depositing a second metal layer on the first side of the SOI substrate after metallizing the first side of the SOI substrate in order to form a reflective surface.

72. The method of claim 66, wherein deeply etching the second side of the substrate to form blades comprises etching to the buried oxide layer of the SOI substrate.

73. The method of claim 67, wherein the protective structure comprises a base wafer.

74. The method of claim 69, wherein the protective lid comprises glass.

75. A method for fabricating a microelectromechanical apparatus, comprising:

    patterning a masking layer on a second side of the substrate that is opposite to a first side of the substrate;

    attaching spacer substrate to the second side of the substrate;

    forming first trenches on the first side of the substrate;

    forming a layer of dielectric material on the first side of the substrate and filling the first trenches with the dielectric material to provide electrical isolation;

    forming vias on the first side of the substrate;

    metallizing the first side of the substrate;

forming second trenches on the first side of the substrate to define structures;

etching an opening through the spacer substrate to expose the masking layer on the second side of the substrate;

deeply etching the second side of the substrate to form blades;

etching to release the structures.

76. The method of claim 75, further comprising attaching a base substrate to the spacer substrate prior to etching through the second trenches.

77. The method of claim 75, wherein the substrate comprises a silicon wafer.

78. The method of claim 75, further comprising attaching a protective lid to the first side of the substrate.

79. The method of claim 75, wherein the dielectric material is silicon dioxide.

80. The method of claim 75, further comprising depositing a second metal layer on the first side of the substrate after metallizing the first side of the substrate in order to form a reflective surface.



81. The method of claim 75, further comprising forming a passivation layer on the first side of the substrate after metallizing the first side of the substrate.

82. The method of claim 76, wherein the spacer substrate comprises a spacer wafer and the base substrate comprises a base wafer.

83. The method of claim 78, wherein the protective lid comprises glass.